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METHOD AND COST OF DREDGING SAND AND GRAVEL BY THE OHIO RIVER SAND CO., LOUISVILLE, KY.

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BY

J. HAMILTON DUFFY

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METHOD AND COST OF DREDGING SAND AND GRAVEL BY THE OHIO RIVER SAND CO., LOUISVILLE, KY.[1]

By J. Hamilton Duffy[2]

INTRODUCTION

This is the first of a series of papers describing dredging methods and costs in recovering sand and gravel from the beds of rivers throughout the United States and deals directly with the methods employed and costs obtained by the Ohio River Sand Co. near Louisville, Ky.

ACKNOWLEDGMENTS

The author wishes to acknowledge the assistance of J. R. Thoenen, mining engineer of the Bureau of Mines, in the collection of data and compilation of this report.

HISTORY

The Ohio River Sand Co. operates two ladder-type dredges in recovering sand and gravel from the bed of the Ohio River in the vicinity of Louisville, Ky.

An industry which may be considered as the forerunner of the river-sand and gravel business in this vicinity was the collection of paving bowlders from the shallow parts of the river prior to 1875. These bowlders were gathered by men wading the river and scooping them up by means of forks. The bowlders were loaded into skiffs and poled or rowed to shore where they were transferred to wagons for delivery in Louisville for paving.

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[1] The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from U. S. Bureau of Mines Information Circular 6421."

[2] One of the consulting engineers, U. S. Bureau of Mines, and vice president, Ohio River Sand Co.

In 1875 J. T. Duffy installed a derrick boat equipped with a clam-shell bucket. This was essentially a wooden hull on which was mounted a derrick with its steam boiler and hoist. By means of the clam-shell bucket operated by the derrick, sand and gravel were dug from the river bottom and dropped into a hopper on the derrick boat. This hopper fed directly to a short trommel with a $\frac{1}{4}$ to $\frac{1}{2}$ inch mesh screen. The sand passed through the screen and was spouted to a wooden barge moored alongside. The coarse material or gravel was discharged back into the river as a waste product.

The sand was then towed to Louisville by steam tow boats where it was unloaded by hand into wagons for delivery to the glass furnaces.

About this time the practice of sawing stone for building purposes was introduced, creating an increased market for sharp hard sand. Later on the market demands varied to include such products as mason's sand, roofing gravel, and finally sand and gravel for concrete.

As the market for river products increased, Mr. Duffy, with Paul C. Barth and James Settle, organized the Ohio River Sand Co. This company in its early years had nothing to do with the production end of the business but confined its activities to selling and distributing the material supplied by Mr. Duffy. In 1906, however, the company took over the whole operation and has continued to the present time.

In 1904 the old derrick boat and clamshell were replaced by a dredge equipped with a centrifugal pump.

This equipment was in turn replaced in 1924 with a modern ladder-type dredge to which a second unit or dredge was added in 1928. Both of these dredges are now in operation and both are described in detail in this report.

The first production of commercial gravel dates from 1904. With the derrick boat and barges unloaded by hand the company produced an average of 100 cubic yards daily which was sold at a price of 90 cents per yard, delivered anywhere in the City of Louisville.

As business increased a stiff-leg derrick was erected on the river bank, replacing the hand labor in unloading the barges. The derrick picked the sand and gravel up from the barges and dropped it into a hopper on the bank from which it passed by gravity to wagons. With this equipment the plant capacity was increased to 450 yards daily.

In 1907 the stiff-leg derrick on the river bank was replaced with a clamshell dredge. This unloaded the material into a hopper on a barge moored to the river bank. A flexible bridge and track connected this barge with an incline on shore. Wooden and steel cars now replaced the wagons and the gravel was hoisted up the incline and over a trestle to be dumped to storage piles on shore. Production was thus increased to 1,000 yards daily.

In 1923 the present land method of handling material was installed. Briefly, it consists of a Brownhoist Bridge crane and system of elevated conveyor belts delivering to truck hoppers, railway cars, or storage piles. The unloading crane is equipped with a 3-yard clamshell bucket and there are 1,500 feet of conveyors. The railway sidings have a capacity of 35 cars. There is room for storing 150,000 tons of material behind concrete retaining walls and the loading hoppers have an additional capacity of 5,000 tons.

In 1915 all wagon hauling for city delivery was replaced by auto trucks and in 1926 all wooden river equipment was replaced by steel.

The present capacity of the plant is 350 tons per hour.

GEOLOGY

The gravel deposits present the familiar characteristics of river-bar geology. Both sand and gravel have been carried down the river for centuries. Flood stages in spring and fall have brought in vast quantities of fresh material to be sorted and deposited according to the vagaries of the changing currents. Thus heavy coarse gravel is found at points of rapid current and fine sand and mud where the velocity of the current diminishes. Constant changes occurring in the direction and velocity of the currents cause the previously formed bars to be reworked and as a consequence coarse and fine gravel is found intimately mixed with large volumes of fine sand.

Formerly many of these bars were above low-water level and could be prospected and tested by dry-land methods. With the recent completion of the Federal system of dams a minimum water level is maintained which inundates practically all the river bars.

At points where the current has a comparatively low velocity the gravel is found covered with from 6 to 8 or more feet of fine sand and mud. In swifter currents coarse gravel with little fine material forms the river bed.

At many points bowlders ranging in weight from 10 to 300 pounds are found scattered over the river bed and imbedded in the gravel.

Many of the gravel bars are rendered commercially useless or at best are workable with difficulty because of water-logged debris, consisting of tree trunks, branches, and stumps carried down the river during flood periods.

During recent years an increasing amount of fine coal has been found in the deposits. It is thought this originates from sunken coal barges which have been lost in the river from time to time.

The commercial gravel deposits as found in place vary greatly both in depth and area. In a distance of 100 feet laterally a good coarse gravel deposit may change to a bar of fine sand.

In addition to the underwater deposits operated by the company it owns two islands in the river. These islands have been tested by churn drilling and the gravel beds contained in them have been shown to vary considerably. The gravel itself varies from 20 to 50 feet in vertical thickness and is overlaid with from 5 to 20 feet of sand. This in turn is covered with 5 to 20 feet of silt or river mud. The larger of these islands comprises 225 acres and is estimated to contain over 16,000,000 tons of sand and gravel.

Within the gravel beds on the islands is a stratum of heavy blue clay from 12 to 18 inches thick. This clay stratum causes trouble in that when dug up with the gravel it does not disintegrate but forms clay balls which are difficult to separate from the gravel.

In the early land grants the bottom of the Ohio River belonged to the owner of the Kentucky shore. This limit was defined as continuing under the river to the low-water mark on the Indiana shore. In most cases surveys have defined just where this low-water mark ends. The system of Federal dams in the river has in many instances permanently raised the established low-water mark on the Indiana shore by inundating considerable area. This inundation however has not changed the ownership of the flooded area. All this area between the low-water mark as established by surveys and the present shore line belongs to the Indiana owner. Therefore, Indiana land owners have been able to exploit these flooded gravel deposits by dredging since the completion of the dams.

CONDITIONS AFFECTING DREDGING OPERATIONS

At present the recovery of gravel is complicated by the condition of the river bottom as left by former dredging operations. The formerly used clamshell and pump dredges excavated shallower holes than the present type of ladder dredge. Pump suctions, as they dug, cut inverted conical openings in the bottom with tops widening as the pump went deeper. This caused caving and as the sides caved an increasing number of bowlders collected at the suction intake. This accumulation finally blocked the suction and the dredge was forced to move. This meant the gravel was recovered from a series of holes which in most cases did not extend to the bottom of the gravel. Considerable of the present dredging is over this uneven bottom from which the commercial material has been only partially removed and in which bowlders are found in troublesome accumulations. These holes have also been more or less filled by river mud and other debris depending on the length of time since they were dug.

Where undisturbed the upper 8 to 10 feet of a gravel bed will usually be found to contain 50 per cent sand and 50 per cent gravel while that below will be more apt to run 75 per cent sand and 25 per cent gravel.

The ladder type of dredge was adopted because it afforded a means of recovering a maximum of gravel with a single passage over the bar. It will also operate with less delay in bottoms that have been worked over by other types of dredges and the accumulated bowlders found therein offer little difficulty to the ladder buckets. A further reason for the choice of the ladder type over the centrifugal pump dredge is its more economical use of power. The centrifugal pump must handle from 80 to 90 per cent water with only 10 to 20 per cent solids in its delivery. This means the expenditure of a large quantity of power for moving water, which is immediately discharged to the river again. In hard-bedded gravel the gravel must often be broken up ahead of the suction by means of a cutter head. This requires further power. The ladder buckets do not require any prior cutting of the bank and deliver the gravel with a minimum of water, thus allowing the power to be expended directly for the recovery of gravel without excessive waste.

This type of dredge is necessarily of larger size and requires much larger capital investment. On the other hand the capital investment per ton of productive capacity is probably on a par with other types of dredges, while the power expenditure and labor cost per ton of material recovered are less.

No accurate data is available regarding the ratio of recovered sand and gravel to the tonnage dug. The reason for this is the variation in the material in the bars. At one place the gravel (3/8 to 2 inches) will compose 30 per cent of the material dug with roughly one per cent oversize and the balance sand. At another point the ratio may be 60 per cent gravel and 40 per cent sand and at still another point one may find 25 per cent gravel and 75 per cent sand.

PROSPECTING

Because of the erratic and constantly changing characteristics of the gravel beds prospecting in advance of actual digging is of little use. A locality prospected one year and found to contain a bed of good gravel may the year following be covered with such an accumulation of drift and debris as to make it unworkable, or the gravel may have been removed by changing river currents.

Where deposits can be reached above water level they are prospected by churn drills.

The usual practice in examining the river bottom is to sound with iron bars or pipes. By this method the operator can obtain some idea of the depth of silt or fine sand overlying the gravel or the presence of gravel itself on the river bottom.

Final prospecting, however, is done by setting a dredge over the location and actually digging. The material dug is examined for quality and ratio of sand to gravel. If not of commercial grade the dredge is moved to another locality.

METHODS OF SAMPLING

Sampling of deposits is not practiced except by visual examination of the material as brought up by the dredge buckets.

Marketable material is sampled and sent to customers for test as required.

CHOICE OF METHOD

Since all the gravel bars lie below water level and are erratic in both area and depth the only practical method of operation is some form of dredging.

The original installation of clamshell and centrifugal-pump dredges has been superseded by the present ladder dredges for reasons already discussed.

Since gravel seldom extends more than 55 feet below the water level the dredges were designed to operate at this maximum depth.

These dredges are designed and constructed to form complete, floating, washing and screening plants although no provision is made on them for storage of finished material. In addition they are provided with living quarters for their crews.

In brief, the method of operation is to dig the gravel by a rigid ladder or continuous bucket elevator. This discharges the material as dug into a hopper in which it is mixed with a sufficient quantity of wash water. It then passes to trommels wherein the sand and larger bowlders are removed from the gravel. The bowlders are discharged through chutes into the river but the sand and gravel go to separate sumps or tanks. From the sumps the gravel is raised by bucket elevator to discharge over a series of sizing screens of such aperature as the market sizes require. After passing these screens the gravel is discharged through chutes or on conveyor belts to barges moored alongside the dredge.

The sand is picked up from its sump by a second elevator and discharged to barges on the opposite side of the dredge or wasted to the river as market requirements demand.

When the barges are loaded they are towed by river steamers to the storage plant on the river bank at Louisville.

The gravel is partly washed in the digging operation. Washing continues through all the screening operations so that when discharged to the barges all silt and mud have been removed. This silt and mud pass back to the river with the excess wash water.

No further sizing is practiced at the storage plant at Louisville.

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EXCAVATING

There are two dredges in operation. The older, designated as No. 4 Digger, is a steel-hulled ladder-type dredge designed and built by the Dravo Contracting Co. of Pittsburgh, Pa. An elevation and plan of this dredge are shown in Figures 1 and 2.

The digging mechanism consists of an endless bucket elevator in which the buckets themselves form the links in the chain. This elevator is mounted on a heavy rigid structural-steel frame hinged at the upper or discharge end and working through the center line of the hull. The lower or digging end is raised and lowered at the will of the dredge operator by means of multiple blocks and cable operating through a steam-driven hoist on the main deck. The operator's station is placed so he has an unobstructed view of the ascending buckets. When digging is interrupted by the buckets encountering heavy debris, such as sunken tree trunks, the operator can raise or lower the ladder by simple manipulation of the control levers.

The buckets discharge into a steel hopper supported by the steel superstructure, and the gravel is fed by gravity to a trommel having $2\frac{1}{4}$-inch round openings. Surrounding the trommel is a jacket screen with 1/8-inch openings. To prevent blinding this jacket, steel rollers are arranged to ride the outside as the screen revolves.

Oversize material which will not pass the $2\frac{1}{4}$-inch openings is discharged into the river as waste. There is not sufficient of this material found to warrant the installation of a crusher to reduce it to commercial size.

The sand and gravel passing the $2\frac{1}{4}$-inch openings but retained on the 1/8-inch screen are chuted to the boot of a continuous bucket elevator similar in construction but smaller in size than the ladder. This elevator discharges over two double-deck vibrating screens. The mesh of these screens is varied from time to time to produce the desired market sizes.

Material passing 3/8-inch round openings is designated as sand and is delivered from the vibrating screens through conveyors or chutes to the river as waste or to a barge moored alongside the digger depending on the demand for coarse sand.

Material passing the 1/8-inch jacket screen drops to a second continuous bucket elevator which discharges to a chute over the side of the digger. This discharge is also either chuted to waste in the river or to a barge as fine sand. The arrangement is such that this fine sand is discharged on one side of the digger while the coarse sand and gravel are discharged on the opposite side.

Both secondary elevators dig their material from steel tanks in which the sand or gravel is deposited from the trommel. The constant agitation of the water and sand or gravel in these tanks by the moving elevator buckets keeps the fine mud and silt in suspension, and they pass off in an overflow from the tank. The elevators thus carry comparatively clean sand or gravel to the vibrating screens or barges.

However, further rinsing is provided by additional wash water playing on the screens as the material is sized.

Ordinarily a coarse and a fine gravel are made as well as two sizes of sand.

By a system of conveyors the two sizes of gravel can be loaded into the same barge or into separate barges at the will of the operator.

The No. 4 digger is steam driven and in average digging has a capacity of 500 tons per hour. Production at this rate requires the handling of 8,000 gallons of wash water per minute or roughly 1,000 gallons per ton of material handled.

The second dredge, known as the Kentucky, is also a steel-hulled ladder-type dredge designed and built by the Dravo Contracting Co. Since this dredge represents more modern construction it will be described in more detail, and is illustrated in Figures 3 and 4.

The hull is of 5/16-inch mild open-hearth steel plate, 155 feet long by 44 feet wide and 8 feet deep, fitted with suitable transverse and longitudinal frames, and bulkheads.

The digging ladder is built of plate and angle sections. It is 88 feet in length and provides a digging depth of 55 feet below the water line. A ten-part line running over sheaves in the bail and bow gantry provides means for raising and lowering the ladder. The ladder is fitted with 86 cast-steel buckets of 4 1/3 cubic feet capacity each. These are fitted with heat-treated steel pins and manganese-steel bushings. The buckets travel at a speed of 33 buckets per minute, corresponding to a digging capacity of 400 tons per hour.

The ladder buckets deliver their load of material to a hopper built of 3/8 and ½ inch steel plate fitted with cast-steel harp (grizzly) bars to prevent the entry of oversize material. These are spaced at 6-inch intervals and set at such an angle that bowlders will move by gravity to the lower end and fall into the waste well. Cleaning bars operated by small steel cylinders are also provided to assist the oversize material on its way to the waste well. These cleaning bars are under the control of the dredge operator.

The material discharges by gravity to a steel washing tank from which it is elevated by a bucket elevator having 4 cubic feet buckets and discharged to a 24-foot rotary scrubber 6 feet in diameter fitted with a 13-foot jacket 9 feet in diameter.

The first 7 feet of the scrubber has $1\frac{1}{4}$-inch round perforations.

The next 6-foot section is a solid plate fitted with lifting angles for the purpose of lifting the gravel and letting it fall and thereby providing more thorough washing.

The third section, 7 feet long, has a screen with $2\frac{1}{4}$-inch perforations.

The outer screen or jacket has 5/8-inch round openings.

Wash water at high pressure is applied on all sections of the scrubber.

All material passing through the screens of the trommel passes over a flat steel pan where it is again subjected to the cleansing effect of high-pressure wash water. From this pan the sand and gravel passes to a second steel washing tank fitted with a suitable overflow for excess wash water and suspended mud and silt. This overflow discharges to the river.

Oversize material from the trommel is discharged into the river.

The washed sand and gravel in the washing tank is elevated by a bucket elevator having buckets of 4 cubic feet capacity each. The bottom spool can be raised or lowered at will. These buckets are of similar design and material as the digging ladder buckets except as to size.

This elevator delivers the material to a 3-way distributing hopper feeding 9 Tyler Hummer screens operating in parallel sets. The upper 6 screens are 3/8 by $\frac{3}{4}$ inch wire mesh and the lower three 5/8 by 5/8 inch wire mesh.

The product passing through the first 6 screens moves to 3 Tyler Hummer screens fitted with 3/16 by $\frac{1}{2}$ inch wire mesh. The oversize and undersize from this set of screens are dropped to bucket elevators and elevated to chutes discharging to barge or river as desired. That material passing over the 5/8 inch Hummer screens drops to a 4 by 8 foot Simplicity mechanically-vibrated screen, where it is drenched with final wash water before its discharge to the gravel barge.

The main conveyor drain plates are lined with 5/16-inch rubber vulcanized to 1/8-inch steel plate.

Gathering pans for sand and all sand hoppers and chutes are lined with 3/8-inch rubber vulcanized to 1/8-inch steel plate.

The two sand elevators are designed for a capacity of from 30 to 60 per cent of the digging capacity. The capacity is regulated by changing the speed of the elevator.

The main ladder engine is a 150-hp., 16 by 16 inch Uniflow condensing engine operating at 200 r.p.m. This engine transmits power through a 6-ply balata belt to the transmission shaft. The digging ladder is operated by two sets of gears from the transmission shaft. This engine drives the ladder, rotary scrubber, and two main elevators.

The rotary scrubber is operated from the main ladder drive through sprockets and chain and two pairs of bevel gears. The main conveyors are operated through sprocket and shaft and sets of spur gears.

The engine driving the high and low pressure centrifugal pumps and the generator is similar to the main ladder engine, but running at 230 r.p.m.

The two sand elevators are driven by individual electric motors through speed reducers.

Wash water is provided by a 12-inch centrifugal pump operating at 900 r.p.m. against a head of 100 feet and delivering 2,400 gallons per minute; a 10-inch centrifugal pump operating at 900 r.p.m. against a head of 40 feet and delivering 1,600 gallons per minute; and a 6-inch centrifugal pump operating at 400 r.p.m.

The first two pumps are belt driven from the auxiliary engine. The 6-inch pump is direct connected to a single-cylinder vertical Engberg steam engine with 4-inch bore and 4-inch stroke.

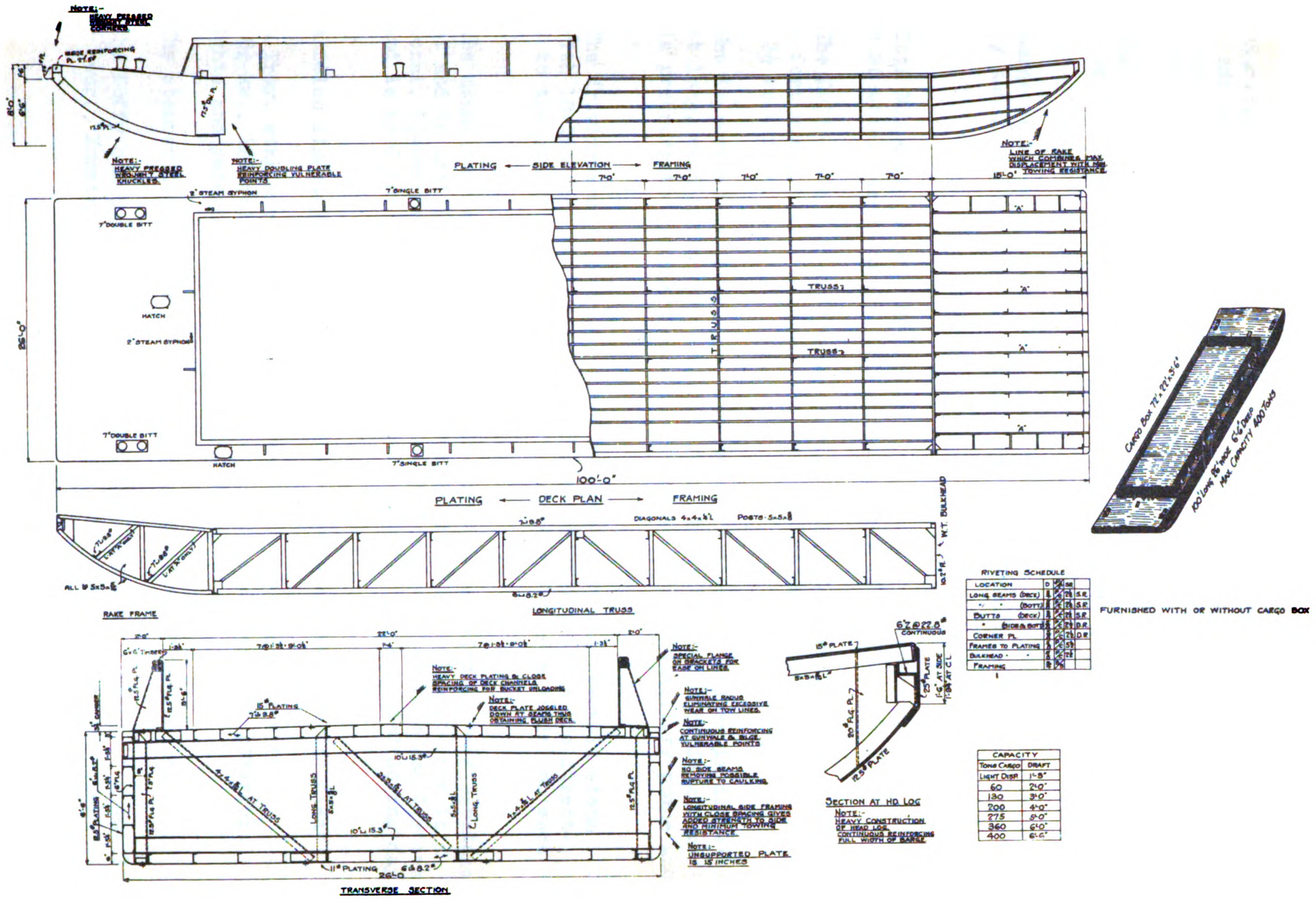
Steam is furnished by two vertical fire-tube boilers of 150-hp. capacity each. They are 6 by 21 feet in size and fitted with 188 2$\frac{1}{2}$-inch tubes 14 feet long. The boilers are designed for 170 pounds steam pressure and are provided with baffles in the upper part of the steam drum to obtain a high superheat.

The ladder hoist is a single-drum, double-reduction, reversible steam engine.

Two double-cylinder, double-gear reduction steam engines are provided for raising the stern spuds.

There are two warping engines, one on each side of the boat. They are four-drum, double-reduction, two-cylinder steam engines. These engines also drive separate drums through another set of gears for hoisting the bow spuds.

The spuds are 36 by 36 inches by 66 feet in size, built of $\frac{1}{2}$-inch steel plate and 8 by 8 by $\frac{1}{2}$ inch angles.


NOTE:- HEAVY PRESSED WROUGHT STEEL CORNERS
WIDE REINFORCING PL. 27.5#
12.5# PL.
17.5# DBL PL.
NOTE:- HEAVY PRESSED WROUGHT STEEL KNUCKLES.
NOTE:- HEAVY DOUBLING PLATE REINFORCING VULNERABLE POINTS
8'-0"
6'-6"
PLATING ← SIDE ELEVATION → FRAMING
7'-0"
15'-0"
NOTE:- LINE OF RAKE WHICH COMBINES MAX. DISPLACEMENT WITH MIN. TOWING RESISTANCE.
2" STEAM SYPHON
7" DOUBLE BITT
7" SINGLE BITT
HATCH
TRUSS
"A"
26'-0"
100'-0"
PLATING ← DECK PLAN → FRAMING
DIAGONALS 4x4x¼L
POSTS 5x5x⅜
W.T. BULKHEAD
10.2# R.
ALL L 5x5x⅜
RAKE FRAME
LONGITUDINAL TRUSS
CARGO BOX 72' x 22' x 3'6"
100' LONG 26' WIDE 6'6" DEEP
MAX CAPACITY 400 TONS
FURNISHED WITH OR WITHOUT CARGO BOX
6'x6" TIMBER
7@1'-8½"-9'-0½"
1'-3½"
2'-0"
22'-0"
NOTE:- HEAVY DECK PLATING & CLOSE SPACING OF DECK CHANNELS REINFORCING FOR BUCKET UNLOADING
NOTE:- DECK PLATE JOGGLED DOWN AT SEAMS THUS OBTAINING FLUSH DECK.
15# PLATING
10" ⊔ 15.3#
LONG. TRUSS
4x4x⅜ L AT TRUSS
12.5# FLG. PL.
11# PLATING
6@8.2#
26'-0
TRANSVERSE SECTION
NOTE:- SPECIAL FLANGE ON BRACKETS FOR EASE ON LINES
NOTE:- GUNWALE RADIUS ELIMINATING EXCESSIVE WEAR ON TOW LINES.
NOTE:- CONTINUOUS REINFORCING AT GUNWALE & BILGE VULNERABLE POINTS
NOTE:- NO SIDE SEAMS REMOVING POSSIBLE RUPTURE TO CAULKING
NOTE:- LONGITUDINAL SIDE FRAMING WITH CLOSE SPACING GIVES ADDED STRENGTH TO SIDE AND MINIMUM TOWING RESISTANCE.
NOTE:- UNSUPPORTED PLATE IS 15 INCHES
15# PLATE
5x3x⅜L
6"Z @ 22.8# CONTINUOUS
25# PLATE
1'-6" AT SIDE
1'-8½" AT C.L.
20# FLG. PL.
12.5# PLATE
SECTION AT HD. LOG
NOTE:- HEAVY CONSTRUCTION OF HEAD LOG. CONTINUOUS REINFORCING FULL WIDTH OF BARGE.

RIVETING SCHEDULE

LOCATION	D	[illegible]	[illegible]	
LONG. SEAMS (DECK)	[illegible]	[illegible]	[illegible]	S.R.
" " (BOTT.)	[illegible]	[illegible]	[illegible]	S.R.
BUTTS (DECK)	[illegible]	[illegible]	[illegible]	S.R.
" (SIDE & BOTT.)	[illegible]	[illegible]	[illegible]	D.R.
CORNER PL.	[illegible]	[illegible]	[illegible]	D.R.
FRAMES TO PLATING	[illegible]	[illegible]	[illegible]	
BULKHEAD " "	[illegible]	[illegible]	[illegible]	
FRAMING	[illegible]	[illegible]		

CAPACITY	
TONS CARGO	DRAFT
LIGHT DISP.	1'-8"
60	2'-0"
130	3'-0"
200	4'-0"
275	5'-0"
360	6'-0"
400	6'-6"

Figure 5.-Details of steel barge

The electrical equipment consists of a Westinghouse Electric 50-kw., 250-volt, 200-amp. generator operating at 1,150 r.p.m. and a 3½-kw., 16-amp., 220-volt generator direct connected to a single-cylinder Engberg steam engine with 4½-inch bore and 4-inch stroke operating at 505 r.p.m.

The usual complement of auxiliary machinery and equipment suitable to this type of dredge is provided, including a well-equipped but small machine shop.

Large well-equipped quarters are provided for the crew and a complete commissary and dining room is also a part of the accommodations.

TRANSPORTATION

Both No. 4 Digger and the dredge Kentucky are served by the steamer Duffy and 20 steel barges of 650 tons capacity each (fig. 5).

The Duffy is a flat-bottomed, steel-hulled, stern-wheel river tow boat, 25 by 135 feet overall with a depth from deck to bottom plates of 5 feet and a draft of 3½ to 4 feet.

She is powered by three fire-tube marine boilers 38 inches in diameter by 26 feet long, each having six 6-inch tubes. These boilers provide steam at 240 pounds pressure to operate the driving engines and all auxiliary pumps and machinery.

The driving mechanism consists of two noncondensing Hegewald steam engines with 15-inch cylinders and 4½-foot stroke. The pistons are direct-connected to the cranks operating the stern paddle wheel, one engine on each side.

The usual complement of boiler-feed pumps, steam winches, and capstans is present and in addition the steamer carries three light plants. One is a Pyle National, 13-ampere, 120-volt generator direct connected to a small steam turbine and is used for emergency or for such lighting as is needed during daylight.

A Delco lighting plant is provided to operate a refrigerating plant.

A Troy, single-cylinder, 8-hp., steam engine belted to a Willey Electric 8¼-kw., 120-volt, 66-amp. generator provides current for powerful search lights and general lighting for night operation.

The steamer is provided with Gardner steam-driven steering gear.

The Duffy can pull 10 loaded barges down stream at a speed of about 3 miles per hour. Running light she has a speed of about 8 miles per hour.

A full double-shift crew consists of 13 men but only 6 men are required for daylight running.

Quarters are provided on board for the crew and in addition a complete kitchen and boarding equipment.

STORAGE PLANT

Sand and gravel brought from the dredges in steel barges is moored to the river bank at Louisville, while the tow boat returns the empty barges to the dredges.

Loaded barges are manipulated under the unloading equipment by means of a double-drum Thomas hoist engine installed on a steel-hulled landing barge or pump boat. This hoist is operated by steam at 100 pounds pressure furnished by a 150-hp., marine-type, water-tube boiler also located on the pump boat. This boat is kept moored at the landing and serves as a landing dock or floating wharf over which supplies are moved to the tow boats. As the name implies, it also supplies power for pumping water from leaking or flooded barges. For this purpose steam from the boiler is used in steam-ejector pumps.

By means of the double-drum hoist loaded barges can be moved in either direction, spotted in position for unloading, and moved as unloading proceeds. The empties are removed and replaced by loaded barges by the same power.

Gravel is unloaded by a Brown-Hoist bridge crane equipped with a $3\frac{1}{2}$-cubic yard clamshell bucket. This crane is of steel construction, cantilever type, with an overall reach of 200 feet. The crane is stationary and all barges must be spotted under it.

Paralleling the river and underneath the crane is a railroad spur track on which cars are spotted for direct loading from the barge when necessary. Ordinary procedure, however, involves discharging the crane bucket to a steel hopper of 25 cubic yards capacity located between the spur and the river bank.

The hopper delivers the material to a 36-inch rubber conveyor belt through a 48-inch steel pan feeder operated through an eccentric. This belt travels at 240 feet per minute and discharges either direct into railway equipment on the spur after passing over a weightometer, or over a shaking screen with $\frac{1}{4}$-inch slotted openings to a second 36-inch rubber conveyor belt.

The first belt is about 75 feet long and operates on an incline of 18 per cent. When discharging over the screen to the second conveyor the gravel is subjected to a final rinsing by a stream of water playing on the gravel as it passes over the screen. The screen is actuated by an eccentric driven from the head-pulley shaft of the first conveyor. Wash water and sand are returned to the river. The initial conveyor is driven by a 10-hp. electric motor operating on 440-volt, alternating current.

The second or main conveyor is 36 inches wide and 600 feet long and runs up an 18-per cent grade for 75 feet and level for the balance of its travel except as it rises to pass over the tripper. This belt is driven by a 35-hp. motor.

This main conveyor delivers through a double-discharge tripper to either of two shuttle conveyors set at right angles to the main conveyor.

The shuttle conveyors are driven by 12-hp. motors. The belts are 36 inches wide and 125 feet long and are reversible in direction. Running in one direction No. 1 shuttle delivers through a movable tripper to a series of 7 concrete bins each of which holds 500 tons. These are used as gravel bins and separate such gravel sizes as have been made on the dredge. No attempt is made to resize or grade either sand or gravel except on the dredge.

Delivery from these bins is to auto trucks through hand-operated flat horizontal gates.

Operating in reverse direction this shuttle conveyor delivers gravel to a ground storage pile.

The No. 2 shuttle conveyor is also reversible in direction, delivering to ground storage in one direction and to 6 concrete bins of 350 tons capacity each in the other direction. This shuttle is used to deliver sand to the bins or gravel or sand to storage, as may be required. The bins store the fine, medium, and coarse sand as delivered by the dredge and discharge to auto trucks.

Either of these shuttles can discharge direct to railway cars on a spur running below them and paralleling the main conveyor.

The No. 2 shuttle conveyor also delivers material beyond the sand bins to a fifth conveyor 24 inches wide which in turn delivers to either of two 24-inch by 260-foot storage conveyors which discharge to ground storage.

In reverse direction this shuttle delivers to an eighth conveyor 24 inches by 150 feet, which also discharges to ground storage.

Either sand or gravel may be handled by these conveyors as exigencies may require.

Centrally located near the main conveyor is the control room from which all belts may be operated or controlled. All belts may be instantly stopped by push-button control from the control room or from points located at 30-foot intervals throughout the system. The first belt carrying material from the hopper under the bridge crane may be operated either from the crane or from the control room.

All belts are driven by separate motors operating on 440-volt, alternating current.

The two long storage belts are run by 25-hp. motors and the short storage belt is operated by a 15-hp. motor.

All 36-inch belts operate at a speed of 240 feet per minute and the 24-inch belts at 320 feet per minute.

The system has a capacity of 350 tons per hour and is lighted so it can be operated day or night.

The yard has a capacity of 150,000 tons of sand and gravel in ground storage and in addition the railway spurs will hold 35 60-ton cars (see fig. 6).

Cars spotted on the river spur are moved by a double-drum Thomas elevator hoist and 1½-inch cable controlled by the crane operator. This hoist is powered by a 75-hp. motor and can handle 15 loaded cars at one time. All chutes discharging material from trippers are lined with rubber. These rubber linings have been found to outlast an equal thickness of steel plate many times.

A gasoline-driven caterpillar crane loads railway equipment from storage piles. This crane is equipped with a ½-yard clam-shell bucket.

For wagon or truck loading from storage the yard is equipped with 4 Barber-Green gasoline-driven portable loaders mounted on caterpillar traction. These loaders are capable of delivering from storage 1 ton per minute each.

There is also provided a Green slip scoop or drag bucket of 1¼ cubic yards capacity for loading railway cars from storage. This is equipped with a Thomas elevator hoist powered by a 75-hp. motor.

The bridge crane is also used in transferring heavy machinery from shore to river equipment and has a capacity of 10 tons. The crane is powered by three separate motors, one for hoisting, one for closing and one for travel. All are of 150 hp. and interchangeable.

For city delivery the company maintains a fleet of 10 Mack and White 5-ton trucks, all of which are garaged in one corner of the yard which is 600 by 800 ft. in size and entirely floored with concrete.

In one end of the garage is a completely equipped machine shop wherein all equipment repairs are made as needed.

In unloading barges three men are employed to clean up after the crane bucket.

All storage piles are confined behind 9-foot concrete retaining walls and the conveyor supports are reinforced concrete with supporting spans of structural steel.

As will be noted in the above description, no provision is made at the land plant for rescreening or grading either sand or gravel. Material is merely transferred from barges to storage bins or railway equipment.

All sizing and grading is done on the dredges and ordinarily two sizes of gravel and three of sand are made. The sand, however, is graded as to color also. Some of the deposits produce a gray sand and others a red sand. These are handled and stored separately for marketing purposes.

Personnel and wage rates

Storage-yard crew:

1 crane man, caterpillar	$6.50
1 hopper tender	4.00
1 car cleaner	5.00
1 wagon loader	6.00
3 barge tenders	4.00
1 operator, bridge crane	7.50
1 belt operator	5.00
1 electrician	7.50
1 car tender	4.00

Steamer Duffy:

1 pilot	10.00 and board
1 engineer	7.00 and board
1 mate	4.75 and board
2 firemen	4.75 and board
1 cook	3.00 and board

Dredge Kentucky:

1 operator	8.00 and board
1 engineer	7.75 and board
1 fireman	4.50 and board
2 deck hands	4.00 and board
1 mate	4.50 and board
1 night watch	4.00 and board
1 cook	3.00 and board

No. 4 Digger:

1 operator	$8.00 and board
1 engineer	7.75 and board
1 oiler	4.00 and board
1 fireman	4.50 and board
2 deck hands	4.00 and board
1 mate	4.50 and board
1 night watch	4.00 and board
1 cook	3.00 and board

COSTS

Period Covered - January 1 to December 31, 1927.

Total material loaded:

Digger No. 4	743,712 tons	(Ladder dredge)
Digger No. 3	73,554 tons	(Centrifugal-pump dredge)
Total dug	817,266 tons	
Bridge crane	634,596 tons	(To storage)

Operating Costs Per Dry Ton Produced

	Labor		Power		Supplies		Depreciation		Total	
	Total	Per ton	Total	Per ton	Total	Per ton	Total	Per ton	Total	Per ton
Digging	$	$	$	$	$	$	$	$	$	$
#3 Digger	7,061.85	0.096	1,692.72	0.023	4,168.51	0.057	2,974.75	0.040	15,897.83	0.216
#4 Digger	22,424.75	.030	10,759.28	.015	36,209.86	.049	22,036.57	.029	91,430.46	.123
Towing Str. Duffy	11,480.05	.014	7,736.71	.009	3,377.80	.004	5,753.03	.007	28,347.59	.034
Storage	18,841.30	.030	4,050.00	.006	30,727.35	.048	11,234.58	.018	64,853.23	.102

Costs are shown for the year 1927 rather than more recent figures because during that year the dredging equipment had a minimum of lost time and operating costs are therefore more truly representative of the capability of the different types of equipment.

No. 3 Digger was a centrifugal-pump dredge operating a 10-inch pump. This unit has since been abandoned and the Kentucky substituted.

Summary of Costs in Units of Labor

Period covered - January 1 to December 31, 1927.

	Digging	Towing	Storage
Labor (man-hours per ton)			
No. 3 Digger	0.12		
No. 4 Digger	.036		
Total digging	.044		
Steamer Duffy		0.022	
Storage yard			0.061
Total man-hours per ton dug	.114		
Power			
Kw.h. per ton			0.255

Labor, per cent of total cost	30.0
Supplies and power, per cent of total cost	49.3
Depreciation, per cent of total cost	20.7

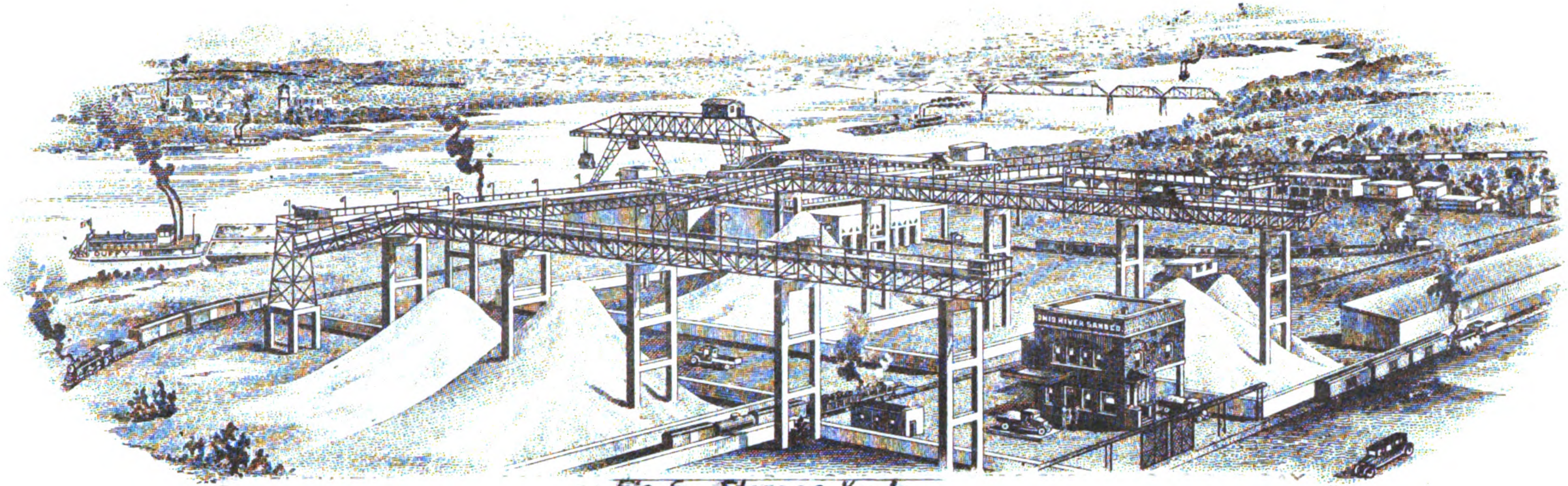

OHIO RIVER SAND CO.

Fig. 6. Storage Yard.